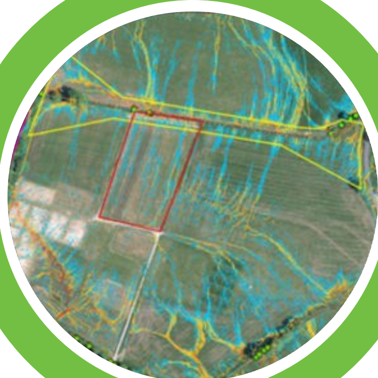
Biomass Connect is funded by:
Department for Energy Security & Net Zero

CASE STUDY BOOKLET

Biofiltration blocks of Short Rotation Coppice willow used for riparian protection to reduce nutrient run-off into the water environment.



Summary/Abstract

Diffuse agricultural pollution is a major contributor to water quality decline in the UK. Using fast growing woody tree species such as Short Rotation Coppice (SRC) willow can provide a simple and economical solution. This case study features a field trial of willow used for riparian protection to reduce nutrient run-off into the water environment. An experimental trial site was originally established at the Agri-Food and Bioscience Institute (AFBI) Research Farm near Hillsborough, Co. Down, Northern Ireland (54.452264, -6.074844) to investigate the extent of Nitrogen (N) and Phosphorus (P) run-off and drainage from an intensive agricultural livestock farming system. The study covers the set-up of the trial, data comparing P export in the surface run-off under SRC willow and grass, and estimated values of the impact of P removal, as well as potential income from biomass.

Background and Objectives

Given the recent focus on water quality decline (e.g. Lough Neagh & Wye Valley) where diffuse agricultural pollution must shoulder some of the blame[1][2], the opportunity for water quality protection using fast growing woody tree species such as Short Rotation Coppice (SRC) willow is emerging as a potentially viable part of the solution. Point and diffuse sources of pollution are contributing to this water quality decline, however, unlike point source discharges (wastewater and sewage discharge pipes) where the problem can be dealt with in a targeted and structured manner, diffuse pollution is more unquantifiable and variable. Diffuse sources of pollution are also affected significantly by soil type, agricultural activity, weather and to an increasing degree, climate change.

The ability of SRC willow/soil systems or biofiltration blocks to bio-filter wastewater from a variety of sources such as wastewater treatment works, septic tanks, agri-food processing and even leachates from land-fill sites, has already been demonstrated and it is believed that this approach could be used to address diffuse pollution from agricultural land[3]. SRC willow is fast growing, takes up large volumes of water and utilises nutrients, in particular Nitrogen (N) and Phosphorus (P), thereby mitigating run-off of these nutrients into ditches, streams, rivers and lakes. At the same time, the crop is a sustainable source of biomass which could be used for on-farm energy generation, biomass fuel supply or other non-bioenergy uses (e.g. bedding, biopackaging, pulp, phytoceuticals etc).

AFBI has been assessing the effectiveness of SRC willow/soil bio-filtration blocks in reducing the overland flow from agricultural land. As part of the EU funded Interreg VA CatchmentCARE project (https://catchmentcare.eu/), bio-filtration blocks have been set up at the base of a sloping grassland site, to investigate how much nutrient (P) can be intercepted and removed from run-off before it enters the stream at the bottom of the slope. Grassland plots, with and without SRC willow/soil bio-filtration blocks, are being monitored and compared over several years to test whether and to what extent SRC willow biofiltration blocks can protect water quality from the overland flow of nutrients.

Description

The biofiltration field trial at AFBI was constructed on a hill slope site and consists of six hydrologically isolated plots (each 0.2 ha) measuring 143 m x 14 m. Run-off from each isolated plot is collected in a trough at the bottom of the hill and directed to separate v-notch weirs with flow proportional monitoring of surface run-off water (Figure 1). The uphill grass land area is essentially managed as with the rest of the farm whereby slurry is applied in accordance with the N. Ireland Nutrients Action Programme 2019-2022[4].

In 2016 this site was repurposed by planting SRC willow at the foot of three of these plots in order to develop long term evidence on whether targeted SRC willow would function as a biofiltration block and provide riparian protection to reduce the overland run-off of pollution into the receiving stream. All plots have been treated in exactly the same way and had similar P indices ranging between Olsen 2 and 3.

The location of the three experimental plots in the farm landscape can be seen in Figures 2 and 3. Furthermore, the Hillsborough research farm was surveyed using LiDAR (light detection and ranging), with this data being incorporated into a Digital Terrain Model (for soil depth and hydrological conductivity). This reveals the areas of hydrological sensitivity (HSA); the areas at greatest risk of generating overland flow as a result of a rain event. These are the areas that were targeted for willow planting as seen by the yellow outline area in Figure 2 and the same area with growing crop two years later in Figure 3.

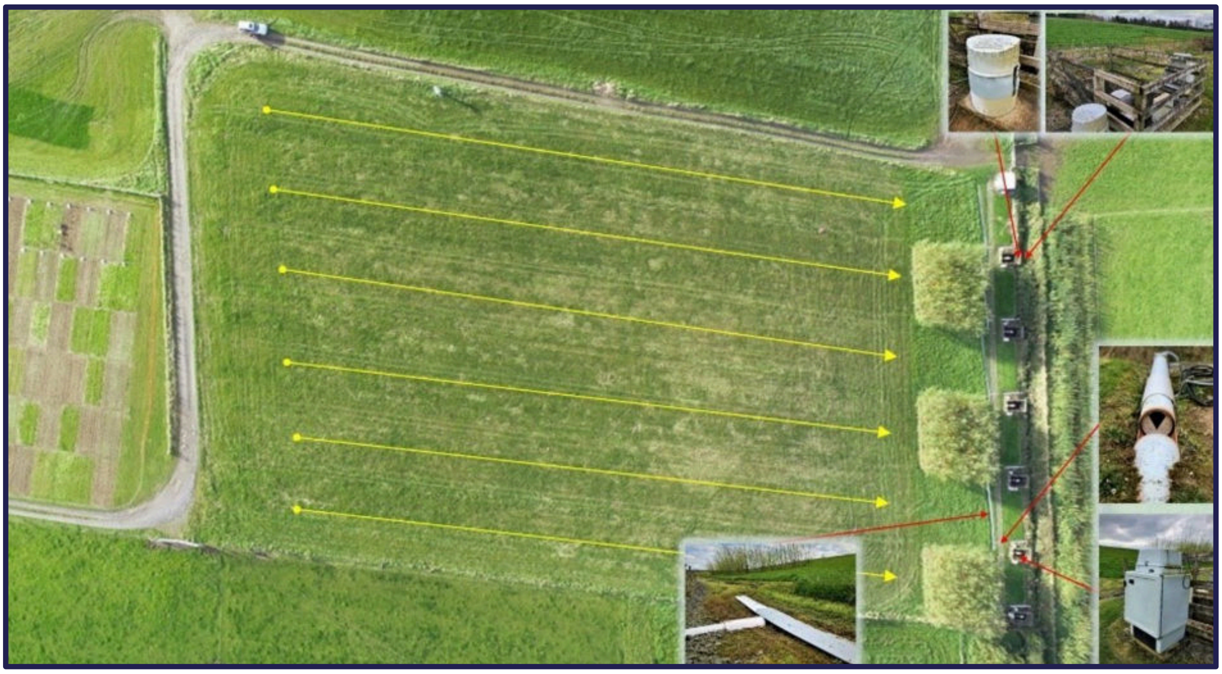


Figure 1: Constructed run-off plots with willow and grass biofiltration blocks

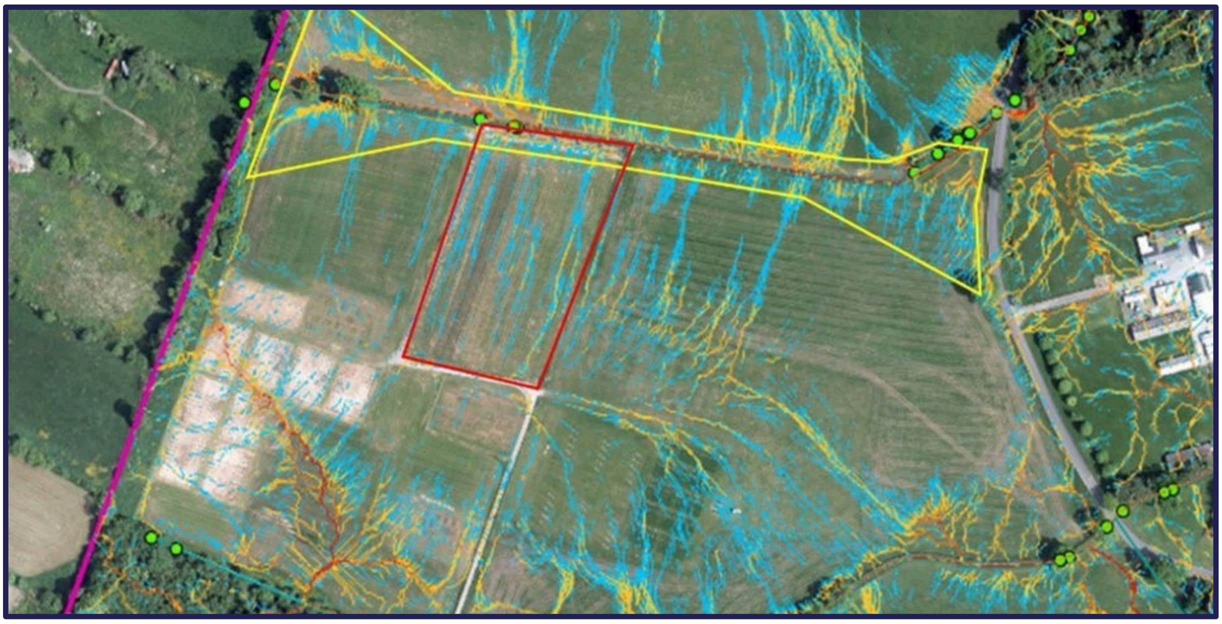


Figure 2. LiDAR imaging indicating overland flow risk hence, the targeted area for planting SRC blocks at AFBI Hillsborough (yellow outline). Replicated run-off blocks as per Figure 1 (red outline).

Figure 3. Mature SRC run-off plots and catchment protection plots.

The willows were established according to best practice guidelines[5]. The plots were sprayed (with glyphosate) in April 2016 and planted in May/June the same year and although planted by hand, the spacing and density of planting was kept the same as would be expected from mechanical planting. This is a spacing of

Figure 4. The sprayed off areas of grass into which 20 cm willow cuttings were planted.

1.5 m between double rows, 0.75 m between the rows in the double rows and the plants were planted 0.45 m from each other within the row. Five double rows were planted giving a buffer strip width of 9.75 m. The willow varieties were chosen from commercial listings and from UK and Swedish breeding programmes to widen the genetic diversity for protection against plant diseases and predation.

The plots were 14 m long x 9.75 m wide. Each block therefore being 0.013 ha in size and containing around 220 willow plants.

On occasions as a result of a rain event, the overland flow is collected by a shallow trench running across the width of each plot as seen in Figure 7. Once triggered the samplers measure the volumetric flow and collect some run-off for lab analysis.

Successes

Early indications suggest that the willow blocks are reducing the run-off of P. Figure 5 indicates a lower average P load accumulation from samples below the willow blocks (blue line) compared to grass controls (red line).

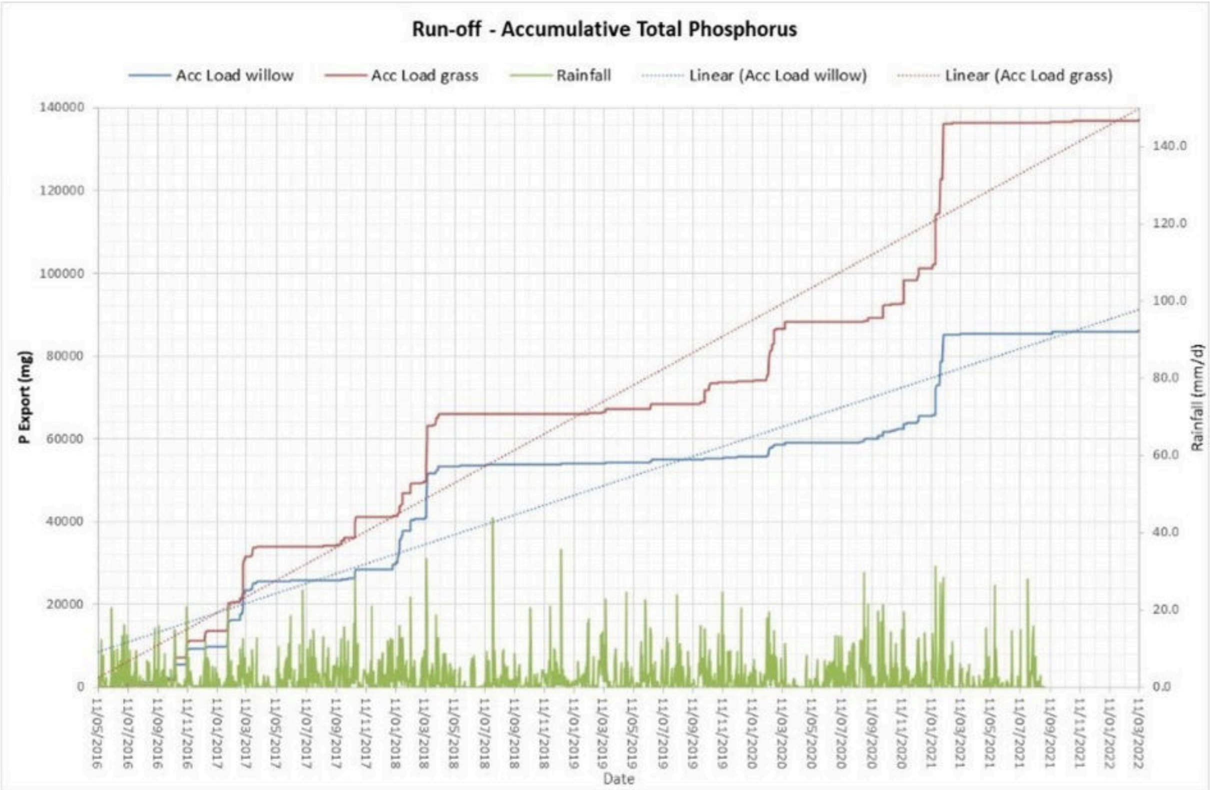


Figure 5. Preliminary results Indicate increasing differences in average P export between grass (red line) and SRC plots (blue line).

Over the years the data indicates a reduction in Total P load run-off of between 20% and 37% with an average reduction of 35%. Furthermore, soil moisture content is consistently lower and hydrological conductivity (measured using Saturo Monitoring) is consistently higher in the willow blocks than the grass plots, revealing likely reasons for these reductions in nutrient run-off.

These results have been consistent over a recent 6-year period and indicate that the targeted placement of SRC willow buffer strips does indeed seem to be reducing the diffuse run-off of P from the agricultural field.

Challenges and Practical Considerations

Although the replicated platform consists of 3 replications of grass and 3 of willow (treatment), there are challenges given the age and integrity of the site. However, the data does indicate a strong effect on reducing P run-off. The construction of a comparative experiment using real world buffer biofiltration plantations is difficult given the infinite variability from site to site.

The plantation targeted using LiDAR and established as in Figure 2 (yellow outline) and growing well in Figure 3 is naturally unique. In order to detect a direct effect of this, it would be necessary to collect long-term water quality data, along with flow volumes, pre-establishment and again long-term data afterwards. Long-term water quality data has been collected at the AFBI Hillsborough Farm and a number of Hydrologically Connected Areas (HCA) have been targeted and planted in this way. There is potential to record some improvements in water quality as a result. However, it is more difficult to decide whether improvements are as a direct result of the bio-filtration or combined to include other actions such as different livestock stocking and management, improved slurry management, manure and dirty water management or simply variable weather patterns, where climate change will almost certainly be playing a role.

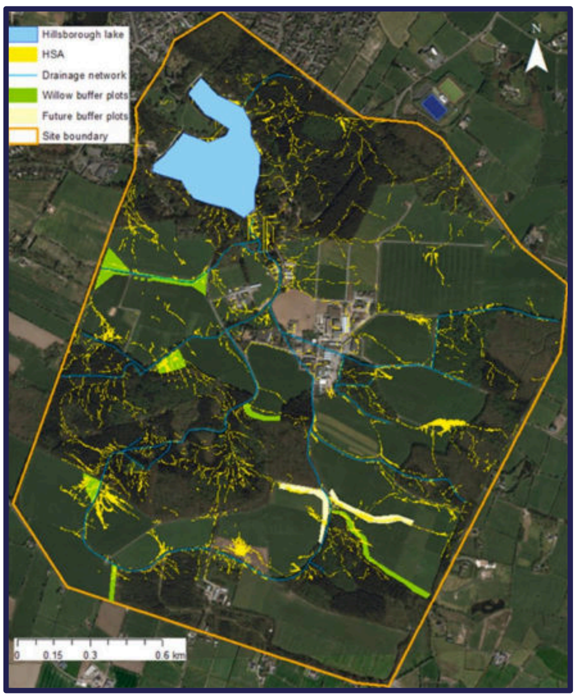


Figure 6. Planting of SRC willow in a number of HSAs at AFBI Hillsborough Farm[8]

The replicated trial was an experiment so all planting and harvesting operations were carried out by hand. Planting was done in April 2016 and the SRC plots were harvested manually using chainsaws and brushcutters every three years between the months of November and March. So far harvesting was completed in 2020 and 2023. The next harvest will be carried out in 2026.

If this type of application is to become a mainstream activity on farms, machinery needs to be developed that can plant and harvest in a low cost, efficient and low impact manner given the likelihood of wetter and therefore less easily managed areas of the farm.

Costs and Benefits

Valuing SRC willow in an Agricultural Environment

If we are to accept that agricultural production systems must no longer focus solely on production efficiency but embrace and adopt increasing measures of environmental sustainability with respect to water, air and soil quality as well as biodiversity and soil carbon net gains, then the targeted planting of SRC willow biofiltration blocks to protect water quality would seem to be a logical and sensible approach. However, understandably, it is clear that farmers and land managers can be reluctant to dedicate areas of farmland from the primary agricultural production focus into less profitable uses.

A further study[6] therefore set out to investigate the economic and environmental return of diversifying into SRC willow in an intensive agricultural landscape. This study utilised the buffered sub-catchment at AFBI Hillsborough (Figure 3) along with real world data to develop a Life-Cycle Assessment (LCA) overview of costs.

Although it is possible that this diversification option can be profitable on its own, dependent on the availability of certain supply chains and harvesting strategies, it generally represents a loss when integrated into a typical dairy farm. However, when a monetised value of certain ecosystem services (nutrient removal) is incorporated, there was minimal impact on the economic return on the dairy land.

Valuing Phosphorus removal from the water environment

The Farmscoper / ADAS estimated values for nitrate, phosphorus and sediment originally based on Chadwick et al (2006) for DEFRA research and expressed in 2021 prices in version 5 of the Farmscoper tool[7] estimate the economic damage from water pollutants across a range of ecosystem goods and services (e.g. drinking water quality, fishing, bathing water quality and eutrophication) and isolate the contribution of agriculture. Based on this the annual value of reducing a kilogram of phosphorus in water from agricultural sources is £39.76.

An approximation for this trial therefore would be:

Average Total P reduction between 2016 and 2021 from the 14m x 9.75m SRC willow plot (0.014ha)	54g
Average Total P reduction per year (= 54/5)	10.8g/y
Average Total P reduction per ha per year	815g/ha/y
Average Social Value of P removal of SRC willow	£32.40/ha/y

SRC production costs, yield potential and uses

As the small trial plots are planted and harvested manually it is difficult to estimate the economics of this venture. However, another Biomass Connect case study (SRC Willow – self supply and use in a farm-scale community heating scheme[9]) provides an indication of the costs involved.

If standard yields are assumed*, then these three SRC plots should be capable of producing circa 1.7 tonnes of boiler ready fuel from every 3-year harvest. This is obviously a very small amount of biomass. The farm in the case study referred to above requires 60 tonnes of woodfuel per year and on average produces one third of their requirement from SRC self-supply. To produce that amount of SRC woodchip would require a total area of SRC buffer strips of 1.4 hectares across the farm.

The size and small-scale nature of SRC buffer strip cultivations is possibly better suited to agroforestry than energy production. Willow can provide a useful fodder addition to the diets of livestock and zoo animals. (For more information see the Chester Zoo case study[10]).The rods would need to be harvested in leaf and moved to a less sensitive area where the animals are located. Animals should not be allowed to graze the SRC in situ as their faeces would add to the nutrient load and defeat the purpose of the buffer strip.

* Willow is harvested green with a moisture content of 55%. The average yield of a hectare is around 55 tonnes of green biomass. This is equivalent to ca. 10 dry tonnes per year or 14 boiler ready tonnes per year.

Lessons Learnt and Recommendations for Future Projects

This is a research project which set out to try to demonstrate and quantify any water quality benefits of SRC willow biofiltration blocks targeted within the agricultural landscape for riparian protection. The run-off platform has been in operation, for varying environmental applications, since the late 1980s and as such, requires significant and on-going maintenance and management. Automated samplers also require continual maintenance and management from which samples need to be collected and flow data downloaded at regular intervals. The research platform is therefore relatively cost and labour intensive while the infrastructure, due to age, can give rise to some intrinsic failure.

Although, the science would require further temporal data to refine the effectiveness of this type of environmental intervention, the results do seem to indicate that a targeted landscape intervention of SRC biofiltration blocks / buffer strips within catchments that are sensitive to excess P loadings, could contribute to mitigating P run-off. A scheme in which replicated, commercial scale plots, targeted within a specific catchment with regular monitoring would seem an obvious next step.

Figure 7. Chris Johnston of AFBI talking to Jeanette Whitaker of UKCEH (who is leading the Biomass Connect project) in November 2023. The SRC plot has 2-year-old stems on 6-year-old stools. Notice the shallow trench to collect overland flow after a rain event (just in front of Chris's feet).

References

1: https://www.agendani.com/lough-neagh-an-ecological-catastrophe/

2: https://www.theguardian.com/environment/2023/may/30/river-wye-has-health-status-downgraded-by-natural-england-after-wildlife-assessment

3: https://storymaps.arcgis.com/stories/5bbeed749d4e46f28b12c0f2367911b1

4: https://www.daera-ni.gov.uk/articles/nutrients-action-programme

5: https://envirocrops.com/resource/short-rotation-coppice-willow-best-practice-guidelines

6: https://pureadmin.qub.ac.uk/ws/portalfiles/portal/410955897/1_s2.0_S2352550923000131_main.pdf

7: https://adas.co.uk/wp-content/uploads/2022/01/FARMSCOPER5_Description.pdf

8: https://www.sciencedirect.com/science/article/pii/S0959652623020942

9: https://www.biomassconnect.org/technical-articles/case-study-src-willow-self-supply-and-use-in-a-farm-scale-community-heating-scheme/

10: https://www.biomassconnect.org/news/new-media/willow-at-chester-zoo/

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Further information can be found on the Biomass Connect website [www.biomassconnect.org] or by contacting the Biomass connect Project Office and referencing Case Study 2.4-2.

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